

curator thoroughly competent for such a charge, but I abstain from entering prematurely into further details.

And now let me turn in conclusion to one more aspect of this great undertaking. We have here collected not only the instruments which represent the most advanced posts of modern science, but we have not a few of the men whose genius and perseverance have led the way thither; men who stand in the forefront of our battle against ignorance and prejudice and against the host of evils which a better scientific education must certainly dispel; we have men whose powers are competent for, and whose very presence is an inspiration to, further progress. But, while taking this first opportunity of offering them a hearty welcome, I shall however best consult both their feelings and your wishes by abstaining from any panegyric upon them in their presence, and by giving them an opportunity of speaking, and you of hearing them, upon some of their own subjects in illustration of the remarkable instruments which they have with so much pains and trouble brought under our view.

SECTION—MECHANICS.

Opening Address by Dr. C. W. Siemens, F.R.S.

IN opening the proceedings of the Conferences regarding Mechanical Science, it behoves me to draw attention to the lines of demarcation which separate us from other branches of natural science represented in this Exhibition.

In the Department of Applied Science we have collected here apparatus of vast historical interest, including the original steam cylinder constructed by Papin in 1690, the earliest steam-engines by Savery and by James Watt, the famous locomotive engine the "Rocket," by which George Stephenson achieved his early triumphs, as well as Bell's original marine engine, and a variety of models illustrative of the progress of hydraulic engineering and of machinery for the production of textile fabrics. In close proximity to these we find a collection of models illustrative of the remarkable advance in naval architecture which distinguishes the present day.

It would be impossible to deny the intrinsic interest attaching to such a collection or its intimate connection with the progress of pure science; for how could science have progressed at the rate evidenced in every branch of this Exhibition, but for the great power given to man through the mechanical inventions just referred to. Yet were Mechanical Science at these Conferences to be limited to the objects exhibited in the South Gallery (and separated unfortunately from apparatus representing physical science by lengthy corridors filled with objects of natural history), we should hardly find material worthy to occupy the time set apart for us. But, thanks to the progress of opinion in recent days, the barrier between pure and applied science may be considered as having no longer any existence in fact. We see around us practitioners, to whom seats of honour in the great academies and associations for the advancement of pure science are not withheld, and men who, having commenced with the cultivation of pure science, think it no longer a degradation to follow up its application to useful ends.

The geographical separation between applied science and physical science just referred to, must therefore be regarded only as accidental, and the subjects to be discussed in our section comprise a large proportion of the objects to be found within the rooms assigned more particularly to physics and chemistry. Thus all measuring instruments, geometric and kinematic apparatus, have been specially included within our range, and other objects such as telegraphic instruments, belong naturally to our domain.

With these accessions, mechanical science represents a vast field for discussion at these conferences, a field so vast indeed that it would have been impossible to discuss

separately the merits of even the more remarkable of the exhibits belonging to it. It was necessary to combine exhibits of similar nature into subdivisions, and the Committee have asked gentlemen eminently acquainted with these branches to address you upon them in a comprehensive manner.

Thus they have secured the co-operation of Mr. Barnaby, the Director of Construction of the Navy, to address you on the subject of Naval Architecture, and of Mr. Froude to enlarge upon the subject of fluid resistance, upon which he has such an undoubted right to speak authoritatively. Mr. Thomas Stevenson, the Engineer of the Northern Lighthouses, will describe the modern arrangements of Dioptric lights, which mark a great progress in the art of lighting up our coasts. Mr. Bramwell has undertaken the important task of addressing you on the subject of Prime Movers, and Prof. Kennedy upon the kinematic apparatus forwarded by Prof. Reuleaux, of Berlin. M. Tresca will bring before us his interesting subject, the flow of solids. Mr. William Hackney will address you upon the application of heat to furnaces, for which he is well qualified both by his theoretical and practical knowledge. Mr. R. S. Culley, Chief Engineer of the Postal Telegraphs, will refer you to a most complete and interesting historical collection of instruments, revealing the rapid and surprising growth of the electric telegraph.

Measurement.—Regarding the question of measurement, this constitutes perhaps the largest and most varied subject in connection with the present Loan Exhibition. In mechanical science, accurate measurement is of such obvious importance, that no argument is needed to recommend the subject to your careful consideration. But it is not perhaps as generally admitted, that accurate measurement occupies a very important position with regard to science itself, and that many of the most brilliant discoveries may be traced back to the mechanical art of measuring. In support of this view I may here quote some pregnant remarks made by Sir William Thomson in his inaugural address delivered in 1871 to the members of the British Association, in which he says—"Accurate and minute measurement seems to the non-scientific imagination, a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labour in the minute sifting of numerical results. The popular idea of Newton's grand discovery is that the theory of gravitation flashed upon his mind, and so the discovery was made. It was by a long train of mathematical calculation, founded on results accumulated through prodigious toil of practical astronomers, that Newton first demonstrated the forces urging the planets towards the sun, determined the magnitude of those forces, and discovered that a force following the same law of variation with distance urges the moon towards the earth. Then first, we may suppose, came to him the idea of the *universality of gravitation*; but when he attempted to compare the magnitude of the force on the moon with the magnitude of the force of gravitation of a heavy body of equal mass at the earth's surface, he did not find the agreement which the law he was discovering required. Not for years after would he publish his discovery as made. It is recounted that, being present at a meeting of the Royal Society, he heard a paper read, describing geodesic measurement by Picard, which led to a serious correction of the previously accepted estimate of the earth's radius. This was what Newton required; he went home with the result, and commenced his calculations, but felt so much agitated, that he handed over the arithmetical work to a friend; then (and not when, sitting in a garden he saw an apple fall) did he ascertain that gravitation keeps the moon in her orbit.

Faraday's discovery of specific inductive capacity, which inaugurated the new philosophy, tending to discard

action at a distance, was the result of minute and accurate measurement of electric forces.

Joule's discovery of thermo-dynamic law, through the regions of electro-chemistry, electro-magnetism, and elasticity of gases was based on a delicacy of thermometry which seemed impossible to some of the most distinguished chemists of the day.

Andrews's discovery of the continuity between the gaseous and liquid states was worked out by many years of laborious and minute measurement of phenomena scarcely sensible to the naked eye.

Here, then, we have a very full recognition of the importance of accurate measurement, by one who has a perfect right to speak authoritatively on such a subject. It may indeed be maintained that no accurate knowledge of any thing or any law in nature is possible, unless we possess a faculty of referring our results to some unit of measure, and that it might truly be said—*to know is to measure*.

To resort to a homely illustration of this proposition, let us suppose a traveller in the unknown wilds of the interior of Africa, observing before him a number of elevations of the ground, not differing materially from one another in apparent magnitude. Without measuring apparatus the traveller could form no conclusion regarding the geographical importance of those visible objects, which might be mere hillocks at a moderate distance, or the domes of an elevated mountain range. In stepping his base line, however, and mounting his distance-measurer, he soon ascertains his distances and observations with the sextant and compass, give the angles of elevation and position of the objects. He now knows that a mighty mountain chain stands before him, which must determine the direction of the watercourses and important climatic results. In short, through measurement he has achieved perhaps an important addition to our geographical knowledge. As regards modern astronomy, this may almost be defined as the art of measuring very distant objects, and this art has progressed proportionately with the perfection attained in the telescopes and recording instruments employed in its pursuit.

By the ancients the art of measuring length and volume was tolerably well understood, hence their relatively extraordinary advance in architecture and the plastic arts. We hear also of powerful mechanical contrivances which Archimedes employed for lifting and hurling heavy masses; and the books of Euclid constitute a lasting proof of their power of grappling with the laws regulating the proportion of plane and linear measurement. But with all the mental and mechanical power displayed in those works, it would seem strange that no attempt should have been made on the part of the ancients to utilise those subtle forces in nature, *heat* and *electricity*, by which modern civilisation has been distinguished, were it not for their want of the means of *measuring* these forces.

Hero of Alexandria tells us that the power of steam was known to the Egyptians, and was employed by their priesthood to work such pretended miracles, as that of the spontaneous opening of the doors of the temple, whenever the burnt offering was accepted by the gods, or as we moderns would put it, whenever the heat generated by combustion was sufficient to produce steam in the hollow body of the altar, and thus force water into buckets whose increasing weight, in descending, caused the gates in question to open.

Unfortunately for them, the Academia de Cimento of Florence had not yet presented the world with the thermometer, nor had Toricelli shown how to measure elastic pressures, or there would at any rate have been a probability of those clear-headed ancients applying the power of steam for preparing and transporting the materials, which they used in the erection of their stupendous

monuments, and for raising and directing the water used in their elaborate works of irrigation.

The art of measuring may be divided into the following principal groups.

First. That of linear measurement, the measurement of area within a plane, and of plane angles; comprising Geometry, Trigonometry, Surveying, and the construction of linear measures, distance meters, sextants and planimeters, of which a great variety will be found within this building.

The subject of linear measurement will, I am happy to state be brought before you by one whose name will ever be remembered as the introducer into applied mechanics of the absolute plane, and of accurate measure, I mean Sir Joseph Whitworth. It is to be regretted, I consider, that Sir Joseph Whitworth adopted as the unit of measure, the decimalized inch, instead of employing the centimetre, and I hope that he will see reason to adapt his admirable system of gauges, also to metrical measure, which, notwithstanding any objections that could be raised against it on theoretical grounds—that, namely, of not representing accurately the ten millionth part of the distance from one of the earth's poles to its equator—is, nevertheless the only measure that has been thoroughly decimalized, and which establishes a simple relationship between measures of length of area and of capacity. It possesses, moreover, the great practical advantage of having been adopted by nearly all the civilized nations of Europe, and by scientific workers throughout the world. Sir Joseph Whitworth's gauges, based upon the decimalized inch, are calculated to maintain their position for many years, owing to the intrinsic mechanical perfection which they represent, but the boon conferred by their author would be still greater than it is if, by adopting the metre, he would remove the last and only serious impediment in the way of the unification of linear measurement throughout the world. A discussion will probably arise regarding the relative merits of measurement *à bout*, of which Sir Joseph Whitworth is the representative, and of measurement *à trait*, which is the older method, but is still maintained by the Standard Commissioners, both in this country and in France.

The second group includes the measure of volume or the cubical contents of solids, liquids, and gases, comprising stereometric methods of measurement, the standard measures for liquids, and the apparatus for measuring liquid and gaseous bodies flowing through pipes, such as gas meters, water meters, spirit meters, of which, likewise a great variety of ancient and modern date will meet your eye, and upon which Mr. Merrifield will address you.

Another method of measuring matter is by its attraction towards the earth, or, thirdly, the measurement of weight, represented by a great variety of balances of ancient and modern construction. These may be divided into *beam weighing machines*, which appears to be at the same the most ancient and the most accurate, into spring balances and torsion balances. The accuracy obtained in weighing is truly surprising, when we see that a mass of one ten-millionth part of a gramme suffices to turn the scale of a well-constructed chemical balance. Perfect weighing, however, could only be accomplished in a vacuum, and, in accurate weighing, allowance has to be made for the weight of air displaced by the object under consideration. The general result is that the mass of light substances is really greater than their nominal weight implies, and this difference between true and nominal weight must vary sensibly with varying atmospheric density.

Weighing in a denser medium than atmospheric air, namely, in water, leads us fourthly to the measurement of specific gravity which was originated by Archimedes when he determined the composition of King Hiero's crown by weighing it in water and in air.

Among measures of weight, may be noted a balance,

which weighs to the five-millionth part of the body weighed, sent by Beckers Sons of Rotterdam; another from Brussels weighing to within a fourteenth millionth part of the weight, in weighing small quantities; a balance formerly used by Dr. Priestley; and Professor Hennessy's standards derived from the earth's polar axis, as common to all terrestrial meridians.

Next comes fifthly, *the Measurement of Time*, which although of ancient conception has been reduced to mathematical precision only in modern times. This has taken place through the discovery by Galileo, of the pendulum, and its application by Huygens to time-pieces in the 17th century. The most interesting exhibits in this branch of measurement are, from an historical point of view, the Italian, German, and English clocks of the 17th century, the Timekeeper which was twice carried out by Captain Cook, first in 1776, and which, after passing through a number of hands, was brought back to this country in 1843, and an ancient striking clock, supposed to have been made in 1348; it has the verge escapement which is said to have been in use before the pendulum. The methods employed in modern clocks and watches for compensating for variation of the thermometer and barometer, are illustrated by numerous exhibits, notably the Astronomical Clock, with Sir George Airy's compensation, which will form the subject of a special demonstration by Messrs. Dent and Co.

The measurement of small increments of time has been rendered possible only in our own days by the introduction of the conical pendulum, and other apparatus of uniform rotation, which alone conveys to our minds the true conception of the continuity of time. Among the exhibits belonging to this class, must be mentioned Sir Charles Wheatstone's rotating mirror, moved by a constant falling weight, by which he made his early determination of the velocity of electricity through metallic conductors; the rotative cylindrical mirror, marked by successive electrical discharges, which was employed by Dr. Werner Siemens in 1846, to measure the velocity of projectiles, and has been lately applied by him for the measurement of the velocity of the electric current itself, and the Chronometric Governor, introduced by him in conjunction with myself, for regulating Chronographs, as also the velocity of steam engines under their varying loads; Foucault's Governor, and a considerable variety involving similar principles of action.

Another entity which presents itself for measurement is, sixthly, that of *Velocity*, or distance traversed in a unit of time, which may either be uniform or one influenced by a continuance of the cause of motion, resulting in acceleration, subject to laws and measurements applicable both in relation to celestial and terrestrial bodies. I may here mention the instruments latterly devised for measuring the acceleration of a cannon-ball before and after leaving the mouth of the gun, of which an early example has been placed within these galleries. Other measurers of velocity are to be found here, Ships' Logs, Current Meters, and Anemometers.

In combining the ideas of weight or pressure with space, we arrive at seventhly, the conception of work, the unit of which is the foot-pound or kilogrammetre, and which, when combined with time, leads us to the further conception of the performance of duty, the horse-power as defined by Watt. The machines for the measurement of work, here exhibited, are not numerous, but are interesting. Among these may be mentioned Professor Colladon's Dynamometrical Apparatus constructed in 1844; Richard's Patent Steam Engine Indicator, an improvement on Watt's, and Mr. G. A. Hirn's Flexion and Torsion Pandynamometers.

Eighth. The Measurement of *Electrical Units*—of electrical capacity of potential—and Resistance, forms a subject of vast research, and of practical importance, such as few men are capable of doing justice to. It may be questioned,

indeed, whether Electrical Measurement belongs to the province of mechanical science, involving, as it does, problems in physical science of the highest order; but it may be contended on the other hand that at least one branch of Applied Science, that of Telegraphy, could not be carried on without its aid. I am happy to say that this branch of the general subject will be brought before you by my esteemed friend Sir William Thomson, than whom there is no one more eminently qualified to deal with it. I may, therefore, pass on to the next great branch of our general subject, the ninth: *Thermal Measurement*.—The principal instrument here employed is the thermometer, based in its construction, either upon the difference of expansion between two solids, or on the expansion of fluids such as mercury or alcohol—(the common thermometer) or upon gaseous expansion (the air thermometer); or again, it may be based upon certain changes of electrical resistance, which solids and liquids experience when subjected to various intensities of heat. With reference to these, the air thermometer represents most completely the molecular action of matter which is the equivalent of the expansibility. I shall not speak of the different scales that have been adopted by Réaumur, Celsius and Fahrenheit, which are based upon no natural laws or zero points in nature, and which are therefore equally objectionable upon theoretical grounds. Would it not be possible to substitute for these a natural thermometric scale? One commencing from the absolute zero, of the possible existence of which we have many irrefutable proofs, although we may never be able to reach it by actual experiment. A scale commencing in numeration from this hypothetical point would possess the advantage of being in unison throughout with the physical effects due to the nominal degree, and would aid us in appreciating correctly the relative dynamical value of any two degrees of heat which could be named. Such a scale would also fall in with the readings of an Electrical Resistance Thermometer or Pyrometer, of which a specimen has been added to this collection by myself.

When temperature or intensity of heat is coupled with mass we obtain the conception of quantity of heat, and if this again is referred to a standard material, usually water, the unit weight of each being taken, we obtain what is known as specific heat. The standard to which measurements of quantity of heat are usually referred is the heat required to raise a pound of water one degree Fahrenheit, or the cubic centimetre of water one degree Centigrade.

The most interesting exhibits in this branch of measurement, are, from an historical point of view, the original spirit thermometer of the Florentine Academia del Cimento, and the photographs of old thermometers; the original Lavoisier Calorimeter for measuring the heat disengaged in combustion, Wedgwood's and Daniell's Pyrometers.

As illustrating modern improvement may be instanced a long brass-cased thermometer showing the variation in the readings, when the bulb and when the whole thermometer is immersed; a thermometer with flat bulb to improve sensitiveness; a thermo-electric alarum, for giving notice when a given temperature is reached; an instrument for measuring the temperature of fusion by means of electric contact invented by Prof. Himly; Dr. Andrews' apparatus for measuring the quantity of heat disengaged in combustion; Dr. Guthrie's diacalorimeter for measuring the conductivity of liquids for heat, and a thermometric tube by Prof. Wartmann for determining the calorific capacities of different liquids by the process of cooling.

Finally, Joule has taught us how to measure the unit of heat dynamically, and the interesting apparatus employed by him from time to time in the various stages of the determination of this most important constant in applied mechanics, are to be found, rightly placed, not among thermometers, and other instruments placed in the physical sections, but among the instruments required in

the determination of three great natural standards—of length, time, and mass, and their combinations.

Another branch of the general subject is the *Measurement of Light*, which may be divided into two principal sections, that including the measurement of the wavelength of lights of different colours, and the angle of polarization, which belongs purely and entirely to physical science; and the measurement of the intensity of light by photometry, which, while involving also physical problems of the highest order, has an important bearing also upon applied science. The principal methods that have been hitherto employed in photometry are by the comparison of shadows, that of Rumford and Bouguer; by employing a screen of paper with a grease-spot, the lights to be compared being so adjusted that the spot does not differ in appearance from the rest of the paper, Bunsen's method; Elster's, by determining in combustion the amount of carbon contained in a given volume of a gas; and the one lately introduced by Prof. Adams and Dr. Werner Siemens, by measuring the variation in the electrical resistance of selenium, under varying intensities of light.

Before concluding, I wish to call your attention to two measuring instruments which do not fall within the range of any of the divisions before indicated. The first is an apparatus designed chiefly by my brother, Dr. Werner Siemens, by which a stream composed of alcohol and water, mixed in any proportion, is measured in such a manner that one train of counter wheels records the volume of the mixed liquid; whilst a second counter gives a true record of the amount of absolute alcohol contained in it. The principle upon which this measuring apparatus acts may be shortly described thus:—The volume of liquid is passed through a revolving drum, divided into three compartments by radial divisions, and not dissimilar in appearance to an ordinary wet gas-meter; the revolutions of this drum produce the record of the total volume of passing liquid. The liquid on its way to the measuring drum passes through a receiver containing a float of thin metal filled with proof spirit, which float is partially supported by means of a carefully-adjusted spring, and its position determines that of a lever, the angular position of which causes the alcohol counter to rotate more or less for every revolution of the measuring drum. Thus, if water only passes through the apparatus the lever in question stands at its lowest position, when the rotative motion of the drum will not be communicated to the alcohol counter, but in proportion as the lever ascends a greater proportion of the motion of the drum will be communicated to the alcohol counter, and this motion is rendered strictly proportionate to the alcohol contained in the liquid, allowance being made in the instrument for the change of volume due to chemical affinity between the two liquids. Several thousand instruments of this description are employed by the Russian Government in controlling the production of spirits in that empire, whereby a large staff of officials is saved, and a perfectly just and technically unobjectionable method is established for levying the excise dues.

Another instrument, not belonging to any of the classes enumerated, is one for measuring the depth of the sea without a sounding line, which has recently been designed by me, and described in a paper communicated to the Royal Society. Advantage is taken in the construction of this instrument, of certain variations in the total attraction of the earth, which must be attributable to a depth of water intervening between the instrument and the solid constituents of the earth. It can be proved mathematically that the total gravitation of the earth diminishes proportionately with the depth of water, and that if an instrument could be devised to indicate such minute changes in the total attraction upon a scale, the equal divisions on that scale would represent equal units of depth. (See NATURE, vol. xiii., p. 431.)

Gravitation is represented in this instrument by a

column of mercury resting upon a corrugated diaphragm of thin steel plate, which in its turn is supported by the elastic force of carefully tempered springs representing a force independent of gravitation. Any change in the force of gravitation must affect the position of this diaphragm and the upper level of the mercury, which causes an air-bubble to travel in a convolute horizontal tube of glass placed upon a graduated scale, the divisions of which are made to signify fathoms of depth. Special arrangements were necessary in order to make this instrument *parathermal*, or independent of change of temperature, as also independent of atmospheric density, which need not be here described. Suffice it to say that the instrument, which has been placed on board the S.S. *Faraday* during several of her trips across the Atlantic, has given evidence of a remarkable accordance in its indications with measurements taken by means of Sir William Thomson's excellent pianoforte wire-sounding machine; and we confidently expect that it will prove a useful instrument for warning mariners of the approach of danger, and for determining their position on seas, the soundings of which are known.

Another variety of this instrument is the horizontal attraction meter, by which it will be possible to obtain continuous records of the diurnal changes in the attraction of the sun and moon as influencing the tides. This instrument belongs, however, rather to the domain of physics than to that of mechanical science.

These general remarks upon the subject of measurement may suffice to call your attention to its importance, several branches of which, those of *Linear*, *Cubical*, and *Electrical Measurement*, will now be dealt with.

The discussions which will follow these addresses will be carried on under circumstances such as have never before co-operated, namely, the presence of leading men of science of all civilised nations, who will take part in them, and the easy reference which can be had to the most comprehensive collection of models of scientific apparatus—both of modern and ancient—which has ever been brought together.

SCIENCE AT THE MANSION HOUSE

FOR the first time probably in the history of this country, science has been publicly acknowledged as a great force or power in the kingdom, on a level with literature and art. This, we think, is the legitimate conclusion to be drawn from the entertainment on Saturday by the Lord Mayor at the Mansion House of so many distinguished representatives of science, following hard as it did upon the opening of the loan collection by her Majesty the Queen. The company was numerous—there were about 300 present—as well as distinguished, and included several eminent foreign representatives of science, who have come over to the opening of the loan collection. The meeting was quite as successful as such meetings usually are, and the speeches on the whole much more sensible and appropriate. The following report of the speeches we take from the *Morning Post*:—

The Lord Mayor, in proposing the toast of the evening, "The Representatives of Science," spoke very happily. We were scarcely, he said, conscious of what we owed to science. If the inventor of the first small crane or lever for lifting water from a well were to come upon the scene now-a-days he would have some difficulty in persuading himself that it was the same world, and not some kind of paradise very far in advance of the world with which, in his day, that person was acquainted. Science was one of the mightiest of all the intellectual pursuits that man could follow. His Lordship said he had an intense admiration for the representatives of literature, but he could hardly express the feelings with which he regarded the men who laboured in the various phases of science. What did we owe to it? and what